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April 14, 1997

Barbara I. McKessock
Contracting Officer's Technical Representative
MS: 301-3
Lewis Research Center
Cleveland, OH 44135-3191

Dear Ms. McKessock:

This interim letter progress report is in regard to NASA Contract NA53-96050 "Power Generator for Interplanetary Missions". This report is for the period 8/14/96 to 4/14/97.

A study was made to determine the size of the thermoelectric module that would be used in the power supply (also known as Powerstick). The heat source planned for the thermoelectric power supply is the 1 watt radioisotope heater unit (RHU).

A preliminary investigation of the design based on experience gained from fabricating similar sized thermoelectric generators indicated that the thermal loss from the generator should be about 0.18 watt, leaving 0.82 watts for the thermopile. The results of the sizing study, based on a $T_H = 250^\circ\text{C}$, $T_C = 25^\circ\text{C}$ and module voltage of 5 volts, are shown in Figures 1 and 2. Figure 1 shows how the module heat flux changes as a function of the thermopile element width. Figure 2 shows how the module width, module length and the side area of the module change with element width.

The heat flux selected for the module should be low to prevent large temperature drops across the module hot and cold interfaces. The side area should be low to prevent excessive heat loss by radiation. The length should be kept short to minimize both the size of the generator and its susceptibility to shock and vibration.

Based on the above considerations and the fabricability of the module, an element size of 0.015 inches (0.381 mm) square was selected. This results in a module length of 0.9 inches (22.86 mm) and a module side dimension of 0.291 inches (7.39 mm)

A large scale layout of the elements and electric contacts for the 18 x 18 element module are shown in Figures 3 and 4. Figure 3 represents the hot side of the module and Figure 4, the cold side. The contacts in both figures are shown as in cross-hatching. The plus and minus electric contacts, which connect to the external load, are at the corner elements in Figure 4 and have square contacts.

The gap spacing between the contacts on the element has been selected to be 0.004 inches (1.016 mm). This provides about 70% contact coverage and we believe provides sufficient allowance for dimensional tolerances and misalignment.

A set of tooling was designed and built to accurately cut the Kapton insulation to the required dimension. Special pressing machines were also designed and built to hot-press both the thermoelectric material "stacks" and the final module. These pressing machines are designed to operate within a vacuum bell jar at a press temperature of 350°C and provide a pressure of 200 lb/in² (14 Kg/cm²).

Module assembly requires that two sets of bismuth telluride material be sliced. The first is a set of eighteen P and N plates which are required to form the "stack" and the second step to cut the stack into "slices" which are bonded to make the module. Both of these cuts were originally made by an outside vendor. These operations are done in series, *i.e.*, plates are cut and then the stack is pressed followed by a cutting of the stack into slices so the module can be pressed.

The time required to make both cuts and lap the pieces to size became excessive and was slowing the development of the module considerably. This was overcome by bringing the cutting operation back in-house to our I.D. saw. Once set up on the I.D. saw, we were able to make the cuts with enough initial precision that the lapping operation was not required any longer. This speeded up the turn around time considerably.

As the first two development modules were made, several minor changes were made in the design of the presses. For instance, it was found that side supports were required in the module press because the individual elements tended to slide sideways during the pressing, throwing them out of alignment.

We have currently pressed three modules. The first one mentioned above. The second had some dimensional problems associated with cutting the "slices" but otherwise appeared to be sound. The third module shown in Figure 5, looks very good and will be used to develop the application of contacts. We also have several other modules in various stages of assembly at the present time.

Different means of applying the contacts are being followed at the same time. We are actually looking at plunge EDM to remove the area between metal sprayed contacts; precision sand-blasting the top of the module to remove the module material where the contacts are later to be formed by metal spraying; sputtering through a mask to form the contacts. These methods will be tried and tested in the coming month.

A preliminary layout of the generator design is shown in Figure 6. This design is based on our previous experience designing and building small low power RTG's. A preliminary heat transfer analysis will be conducted based on this design and modifications made as required. We plan to make an assembly mockup of this generator during this phase of the program.

Module testing should start in about a month. The exact start of testing will depend of the success with applying the contacts. As soon as we produce a module that passes our acceptance tests, we plan to ship at least one to J.P.L. for confirmatory testing.

The program appears to be on schedule and without major problems. The successful application of low resistance contacts is the next critical step in the development of the module.

If there are any questions on the program or this report please contact me.

Sincerely,

John C. Bass
Program Manager

Enclosure(s) 6

CC: JPL

Figure 1: Module Heat Flux - VRS Element Width

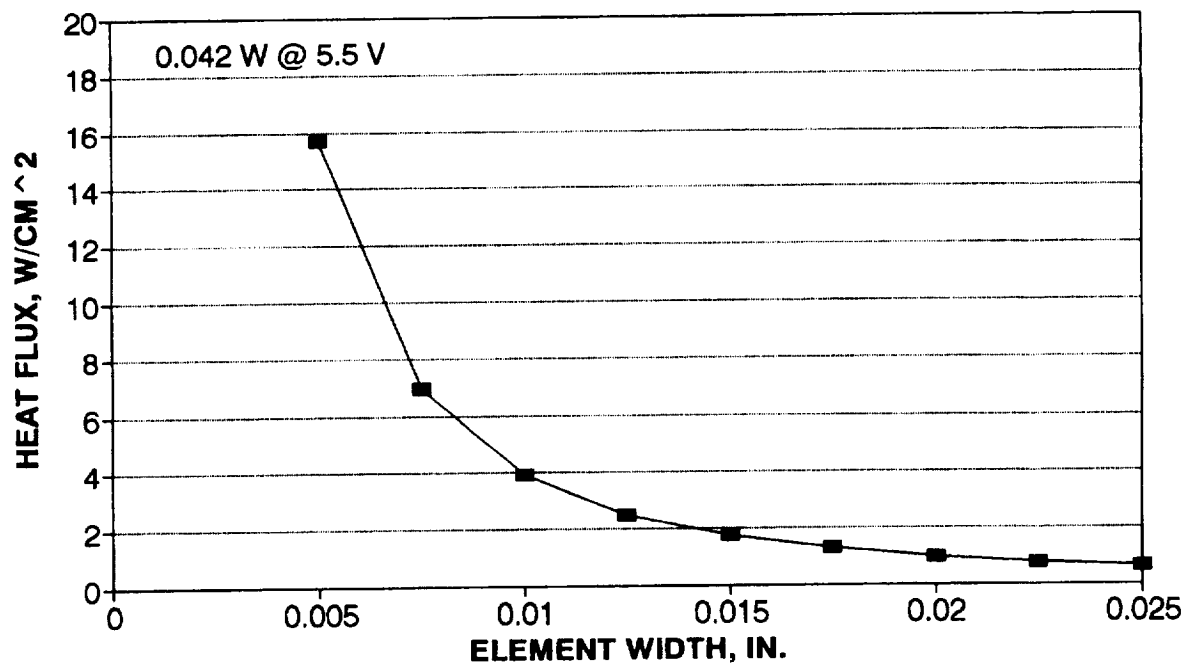


Figure 2: Module Length, Width and Side Area - VRS Element Width

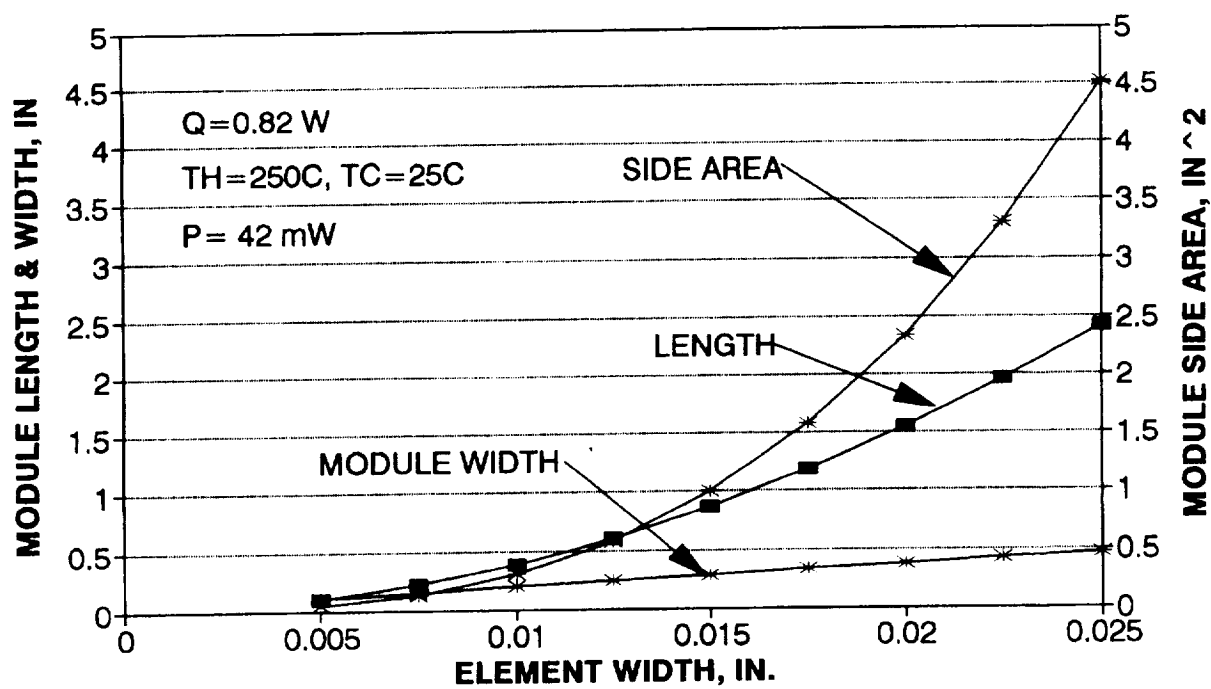


Figure 3: Module Pattern - Hot Side

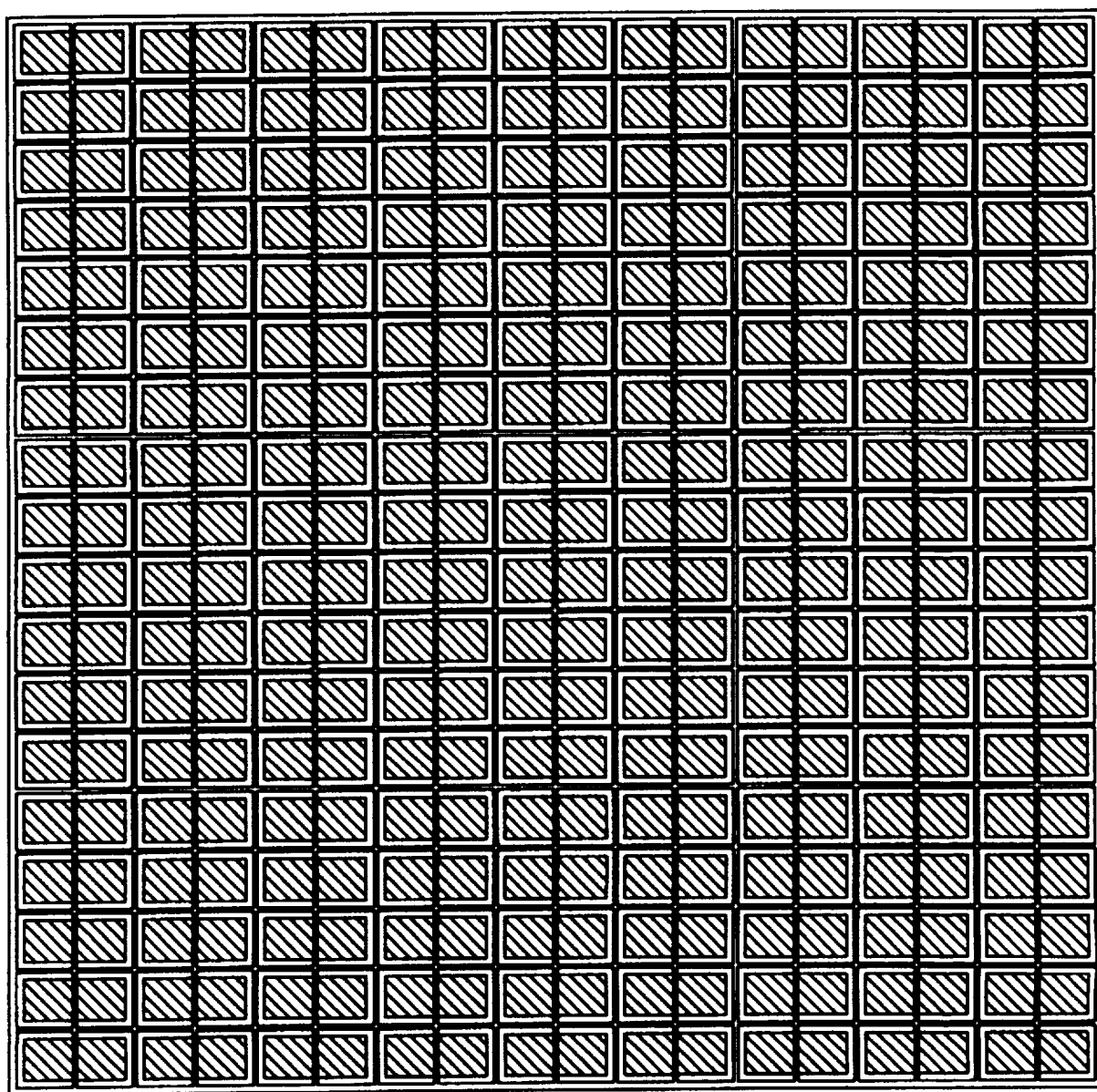
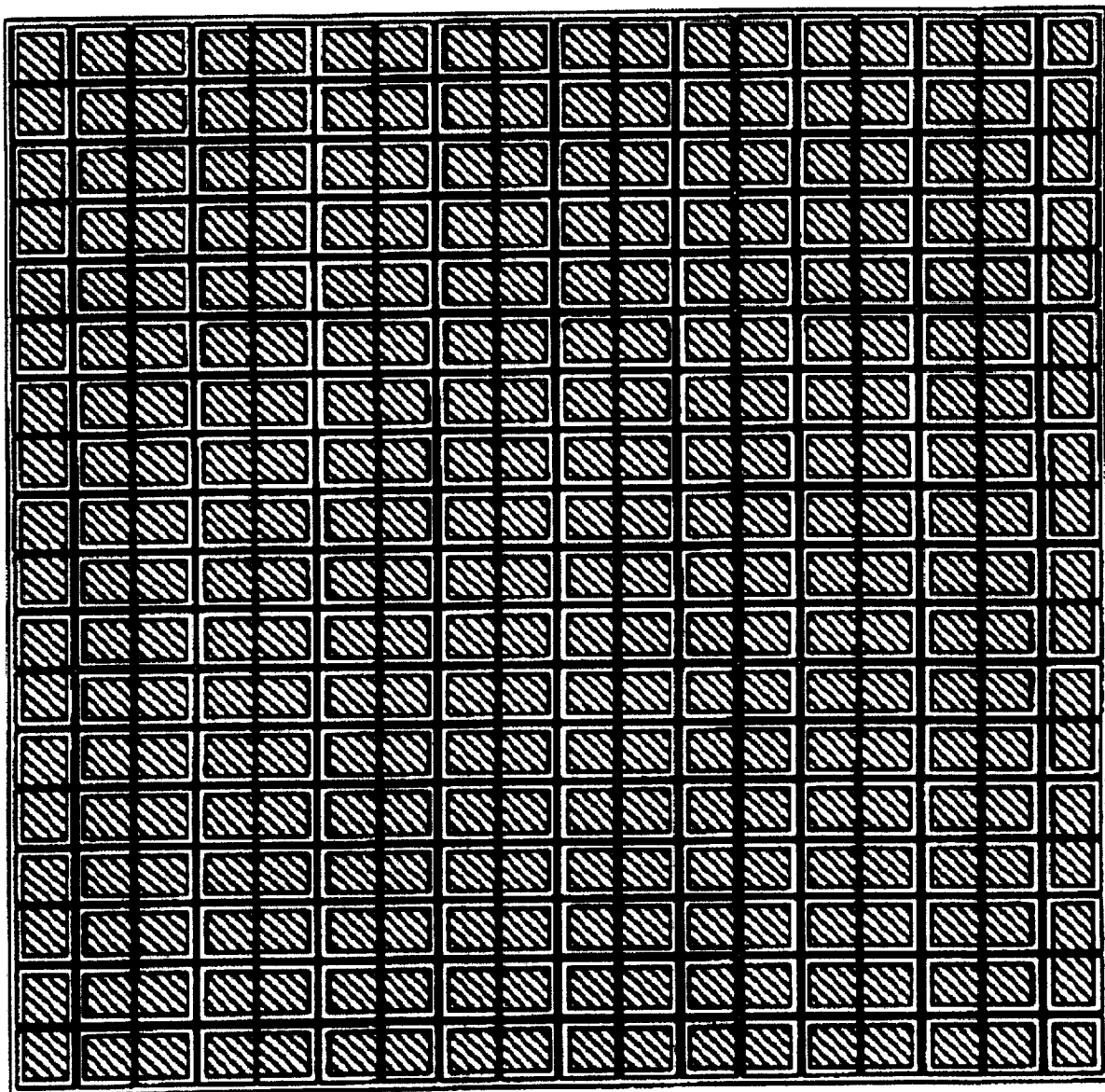


Figure 4: Module Pattern - Cold Side



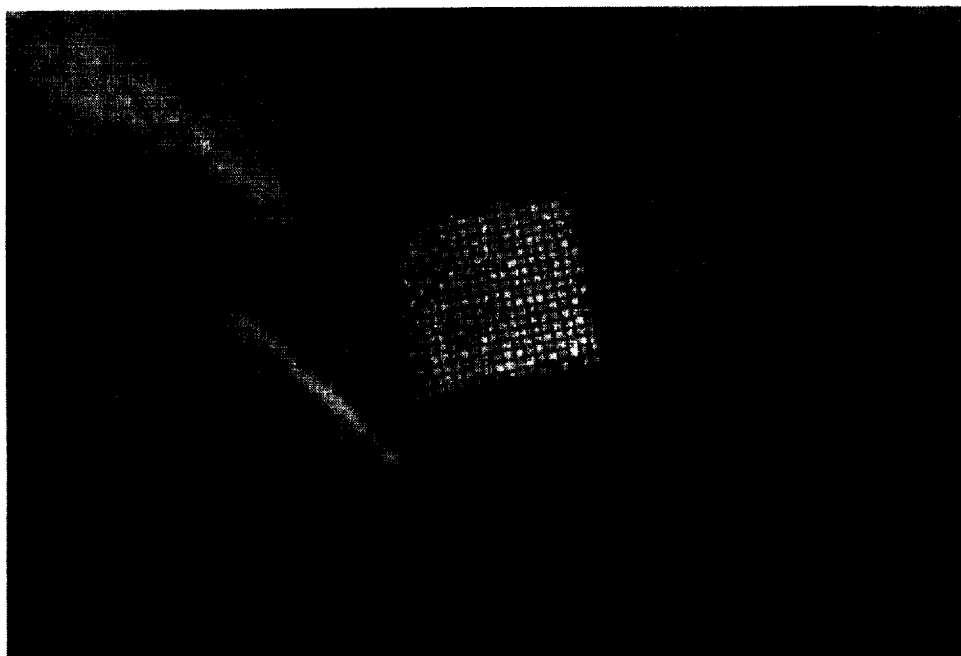


Figure 5: Trial Module for Powerstick - 18 x 18 Matrix of 0.015 Inch Square Elements

Figure 6: Conceptual Layout of Powerstick Generator

